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Research Highlights

- Vansteenkiste *et al.* studied cyclists' viewing behaviour to test the two-level model of steering
- This model has significance for the importance of areas in the visual field but has no bearing on fixation strategy
- Although well conducted, the cycling study failed to include the *guidance level*
- The *stabilization level* differed considerably from that in the real world due to very narrow lanes
- The cycling study may be of interest for 'precision steering'

Studying the role of vision in cycling: Critique on restricting research to fixation behaviour

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Abstract

In a recent study published in Accident Analysis & Prevention, Vansteenkiste *et al.* (2013) –as one of the first in this field– investigated the visual control of bicycle steering. They undertook the interesting task of testing cyclists' eye fixation behaviour against Donges' two-level model of steering, i.e. the guidance level to anticipate alternations in the course of the road and the stabilization level for lane keeping. Although the laboratory experiment itself is well conducted, we believe that its results cannot be used to test the two-level model of steering as developed for driving. The test track was only 15 m long, was completely straight and was known in advance. Accordingly, it did not provide adequate conditions for testing the guidance level. Furthermore, as the experimental lanes were much narrower than real-world cycling lanes, the stabilization level differed considerably from that in the real world. The study by Vansteenkiste *et al.* (2013) may provide valuable insight into the role of vision in 'precision steering', but, as we discuss in the paper, more elaborate research paradigms are needed to achieve more comprehensive knowledge of the role of vision in real-world cycling and cycling safety.

Key words: bicycling, cycling safety, single-bicycle crashes, two-level model, fixation behaviour

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1 Introduction

Bicycle use and cycling safety are important topics in transport policy and research (European Commission 2010). Single-bicycle crashes, i.e. falls and obstacle collisions, are a growing concern for cycling safety in countries where cycling is common, such as Belgium and the Netherlands (see e.g. Schepers 2012, Dhondt *et al.* 2013, De Geus *et al.* 2012). It has been found that vision plays an important role in single-bicycle crashes (Schepers and Den Brinker 2011) and knowledge about its role in cycling is essential for understanding bicycle crashes and the development of preventive measures. Vansteenkiste *et al.* (2013) recently published a study in *Accident Analysis and Prevention* in which they explored the interesting question of whether the visual control of bicycle steering could be explained by the two-level model of steering (TLMS) as developed for car driving (Donges 1978). According to the model, driver steering behaviour is conducted at two parallel levels:

1. the *guidance level* involving the perception of the instantaneous and future course of the road and the response to it in an anticipatory open-loop control mode;
2. the *stabilization level* whereby any deviation between the vehicle's actual path and its desired path is compensated for in a closed-loop control mode.

Guidance involves anticipation on changes in the road's course, while stabilization refers to lane keeping, i.e. maintaining lateral position. Vansteenkiste *et al.* (2013) studied fixation behaviour of cyclists who were required to ride in a short, straight, narrow lane.

To date, theoretical models on cycle behaviour and research paradigms applicable to the understanding of the cycling task are scarce (Twisk *et al.* 2013, Schepers *et al.* 2013). Studies, such as the study by Vansteenkiste *et al.* (2013) that aim to contribute to the development of such a theoretical understanding are of great value, as they advance the field by generating debate on methods, validity and generalizability. In that context, this communication needs to be understood as a critical appraisal of the suitability of the experimental paradigm for the authors' aim, namely, the study of visual control of steering in relation to safety. Note that, at times, the research undertaken by Vansteenkiste *et al.* (2013) will be referred to as 'the cycling study'.

2 Evaluating the task

To examine whether the visual control of bicycle steering can be explained by the TLMS, Vansteenkiste *et al.* (2013) measured fixation behaviour of cyclists riding 15-metre lanes with widths of either 10, 25, or 40 cm indoors, in a gymnasium. Participants were asked to cycle the lane at self-selected speeds (low, preferred, or high) without crossing the white tape delineating the lane edges. In the introduction, the authors argue: "If this model can be applied to cycling as for driving, cyclists would mainly look at distant points while they maintain centred in the lane by attending the proximal pathway peripherally." As the results of the cycling study showed that "In contrast to the two-level model of steering during car driving, the near region was actively looked at.", the authors concluded that the fixation behaviour of the participants could only partly be explained by the two-level model.

There is an important difference between the design of the experimental circuits used in car driving studies and those used in this cycling study. The former generally used simulated winding road circuits (requiring *guidance*), with realistic lane widths (requiring only modest *stabilization*) (Land and Horwood 1995, Donges 1978, Brooks *et al.* 2005). For instance, Donges (1978) studied participants' path along a simulated 3,2 km winding two-lane road. He showed that drivers constantly steered to stay in their lane (*stabilization*), but also steered some time before entering curves to anticipate (*guidance)*. The cycling study used very short (15 metres long), straight lanes that participants were able to observe before they began the task. As it was performed indoors on a smooth surface without irregularities or unexpected events, this means that the task did not incorporate the *guidance level*.

As regards the *stabilization* level, it should be noted that the TLMS was developed for four-wheeled vehicles and, given the fundamental differences between them and single-track vehicles, application of the TLMS to the latter is problematic. Riding a single-track vehicle requires steering input not only for lane-keeping but also for balancing. In the absence of speed a two-wheeler falls either to the left or right. Maintaining the balance of a moving bicycle requires the rider to steer into the direction of the undesired fall so that the wheel contact points are back under the centre of mass of the system (Kooijman *et al.* 2011). Critical to interpretation of the results of the cycling study is the lateral road space needed for balancing a bicycle. From the bicycle model presented by Meijaard *et al.* (2007) and steering motions observed during normal cycling (Van den Ouden 2011), it has been estimated that the necessary lateral space at a forward speed of 18 km/h is around 40 cm. Cyclists at normal speeds are able to reduce this space to around 20 cm with more active steering control (Godthelp and Wouters 1979). The experimental lanes used in the cycling study were extremely narrow (10, 25 or 40 cm; see Figure 1 for an impression of these widths), imposing severe constraints on the *stabilization*. Not surprisingly, it was found that participants who cycled in a 10 cm wide lane (about the width of a normal edge line) were able to keep the bicycle within this lane for only about 60% of the time. Given that the Flemish design standard indicates a minimum width of 175 cm for bicycle tracks (Flemish Government 2012), the laboratory task does not mirror real life lane-keeping.

>>>> Insert Figure 1 about here.

3 Testing the model

Even if an experimental task resembling every day cycling circumstances were used in the cycling study, the interpretation would still be questionable. The reasoning by Vansteenkiste *et al.* (2013) is based on the assumption that the TLMS makes predictions on fixation strategy. This is not the case; the model makes predictions only on which areas in the visual field are of importance (Land and Horwood 1995, Donges 1978). The ambient-focal dichotomy (Leibowitz and Post 1982, Leibowitz and Owens 1977) helps to explain that the frequency of fixations on a certain area do not necessarily correspond with the importance of visual input from this area. For some ‘focal’ processes (for instance object recognition), the fovea should indeed be directed to the relevant information (*i.e. focal vision*). However, other processes such as motion perception, are equally effective if the relevant area is in the retinal periphery (*i.e. ambient vision*), i.e. if the area is not fixated. This focal-ambient dichotomy corresponds nicely with Donges’ *guidance* and *stabilization* level (Schieber *et al.* 2008). The fact that car drivers rarely fixate the near road (Land and Lee 1994) is thus unrelated with the importance of this area (Salvucci and Gray 2004, Land and Horwood 1995). It follows then that the viewing patterns identified in the cycling study cannot be related to the validity of the TLMS.

4 Discussion

What is the reason for the difference in gaze behaviour between the cycling study and the car driving studies? We think it may be that, due to the experimental cycle lanes being very narrow, lane keeping became a precision task requiring focal vision. The approach and findings of the research by Vansteenkiste *et al.* (2013) may be relevant to cycling safety in situations requiring precision steering, e.g. negotiating hazards such as potholes, rain puddles, or slippery drain covers on narrow bicycle tracks. Resulting fixations in the near region could interfere with other tasks which primarily rely on the focal visual channel (Horrey *et al.* 2006), e.g. scanning for traffic while crossing an intersection. This could be tested by observing cyclists' viewing behaviour near intersections, e.g. less fixations on traffic and more on road surface hazards (as an example of studying intersection safety using viewing behaviour, see e.g. Summala *et al.* 1996). Alternatively, one could use a laboratory setting such as the cycling study, to determine the chance that important peripheral information goes unnoticed, e.g. by adding stimuli next to a cycle lane to which cyclists need not respond directly, but are asked for afterwards (see e.g. De Waard *et al.* 2010). This could yield some very valuable data with regard to overload in the focal visual channel and capability of the ambient visual channel to alert the focal channel to the occurrence and location of important events.

Identifying which areas in the visual field are critical to safe cycling (e.g. Fabriek *et al.* 2012) and how visible or conspicuous information needs to be to avoid single-bicycle crashes is important as well (e.g. Schepers and Den Brinker 2011). Given the findings emanating from research into visual control and car driving, it would appear that experimentally manipulating the dimensions of information helps to study which parts of the visual field are important, e.g. occluding part of the visual field (near, far, peripheral, central, etc.) (Schieber *et al.* 2008, De Waard *et al.* 2004).

To conclude, the research paradigm used in the cycling study has shed light on the role of vision in ‘precision’ steering, but more elaborate research paradigms are needed to test the complexities of the role of vision and the applicability of Donges’ TLMS to the cycling task.

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